Constellation-X Facility Science Team Meeting (FST) — Oct. 14/15, 2004

Constellation X

The Constellation X-ray Mission

SXT Mirror Segment Development

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The Basic Process and Axial Figure Metrology

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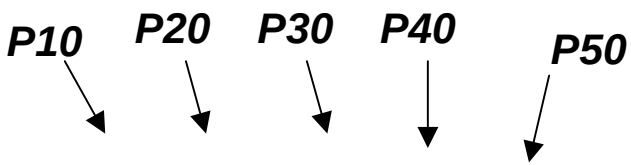

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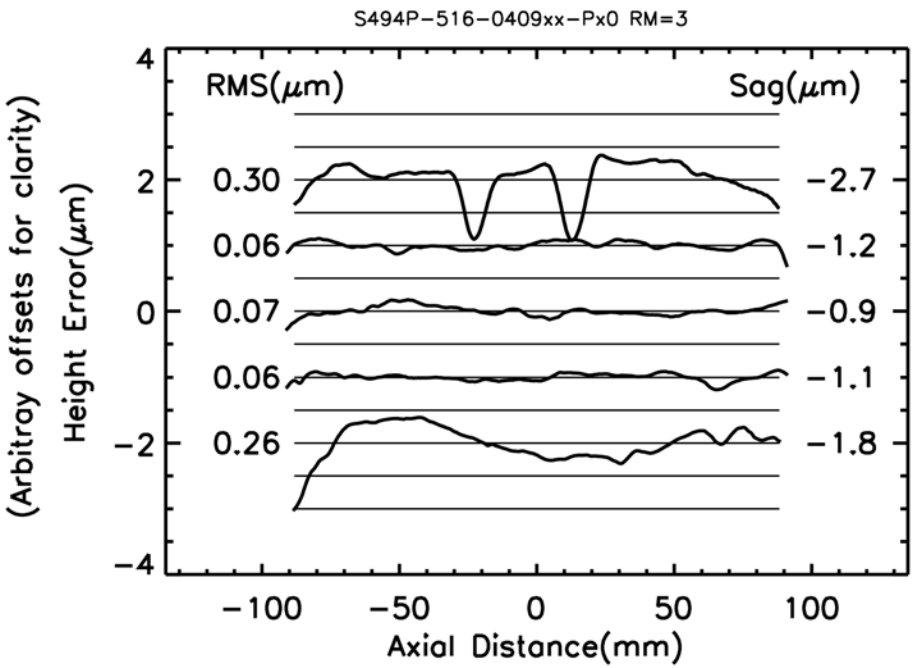
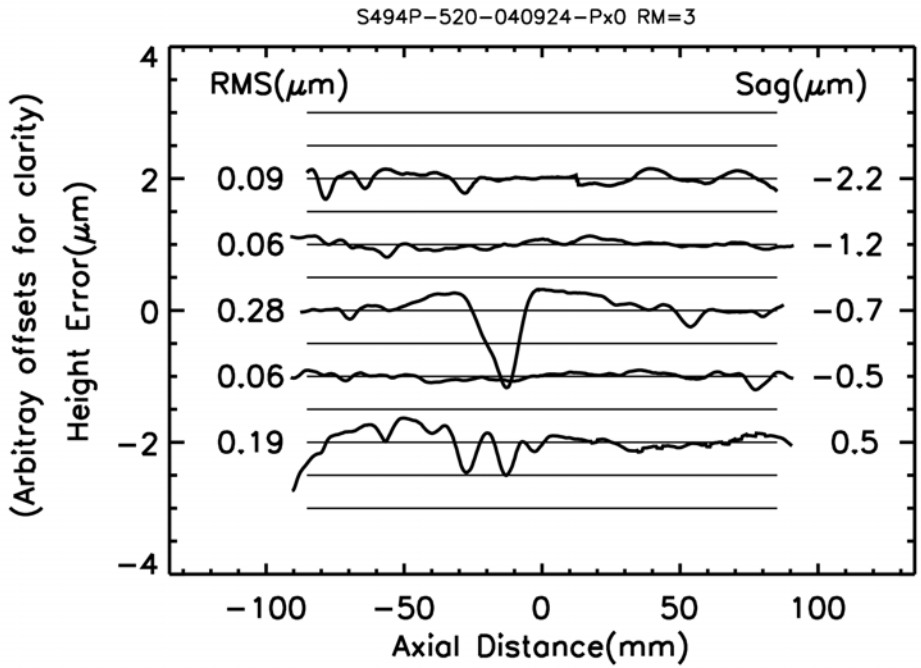
Summary of Work and Progress since Last FST

- Improved mirror fabrication facility environment for cleanliness
  - Resurfaced the interior of the oven
  - Enclosed the glass forming in clean tents
- Started the process of understanding gravity and thermal distortion of the forming process
  - Finite element analysis (both mechanical and thermal) developed under contract with Swales Aerospace
  - Work suspended pending resumption of funding
- Acquired and used for the first time forming mandrels that meet Con-X/SXT baseline requirement
  - Two whole-shell mandrels fabricated by Rodriguez Precision Optics and refigured by the Optical Engineering Branch of GSFC (Diameter 500mm)
  - Two segmented/slab mandrels fabricated/refigured by Zeiss Laser Optics, GMBH (Diameter 1600mm)
- Formed substrates that arguably already meet SXT requirement without epoxy replication: 2.4″ vs. 2.0″ axial slope RMS requirement (2.4″ includes metrology noise which can no longer be neglected)
- Once replicated, these substrates/replicas are expected to exceed the requirement, and to be close to reach the SXT goal of 1.0″ axial slope RMS

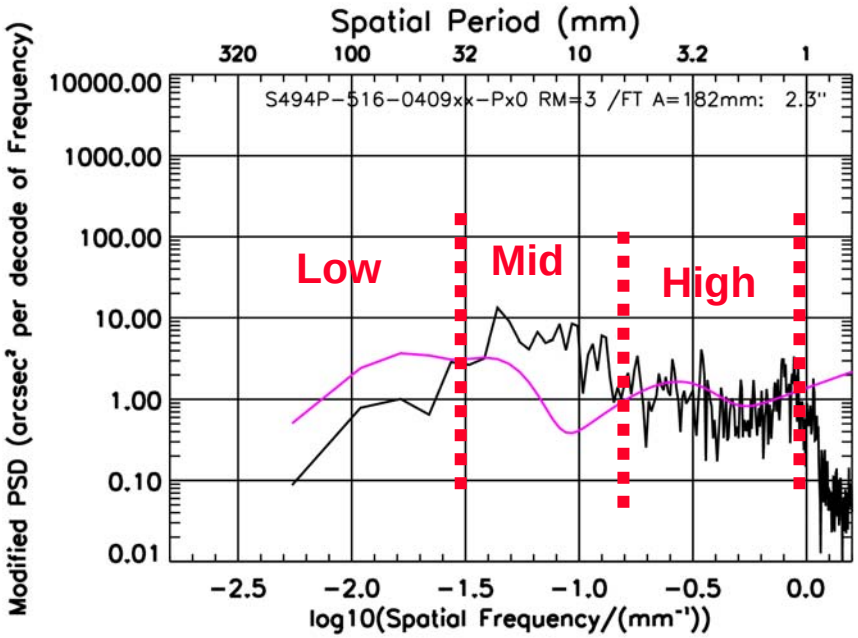
Axial Figures of Two Recent Substrates

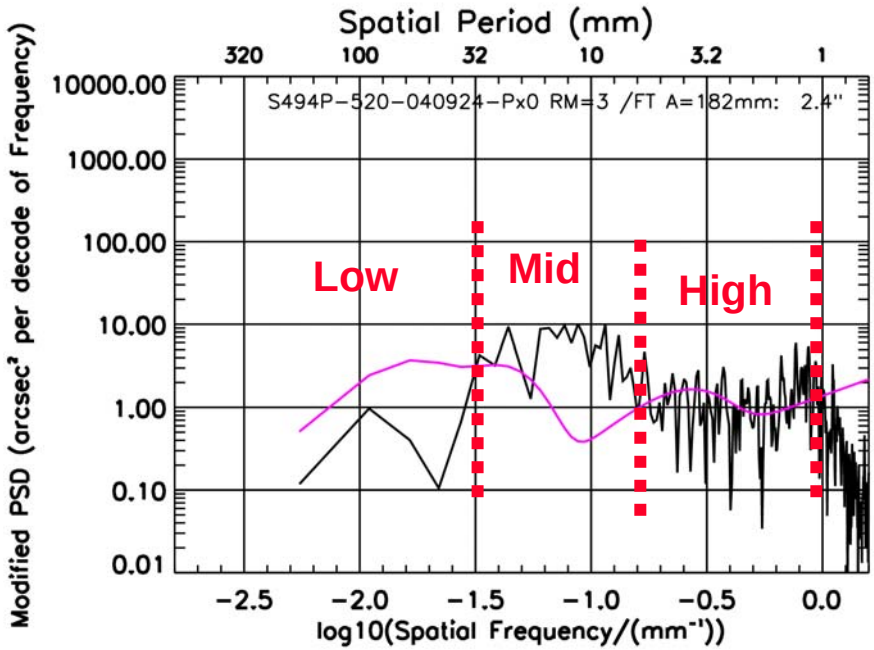




- **Achievements: Axial slope height error: 60nm RMS (requirement 50nm)**
- **Problems:**
  - **Several significant craters caused by dust particles sandwiched between the forming mandrel surface and the substrate, wreaking havoc to the quality of the substrate**
  - **Some incomplete forming or residual thermal stress causing the azimuthal edges to distort**

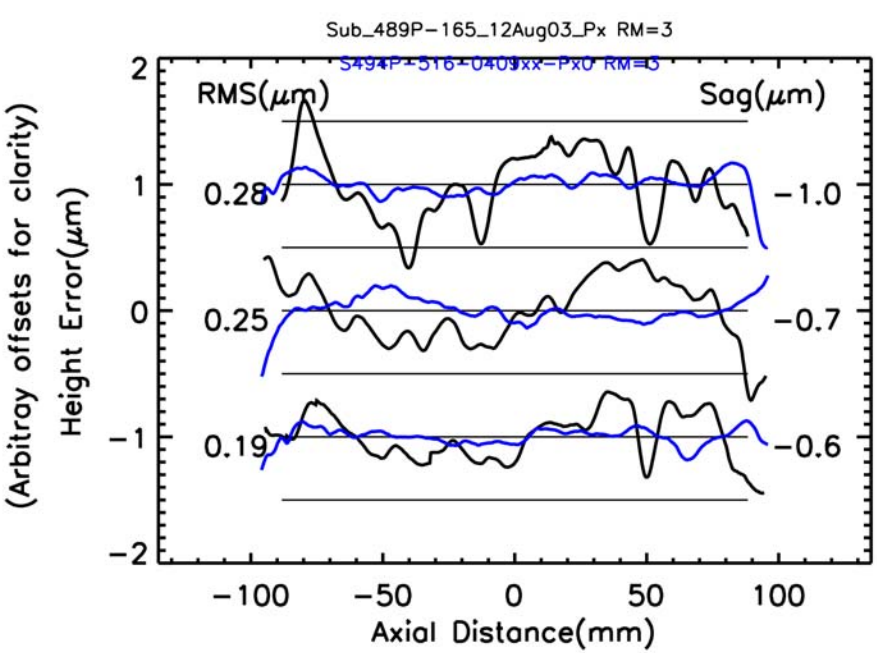
The Same Two Substrates in Spatial Frequency Domain

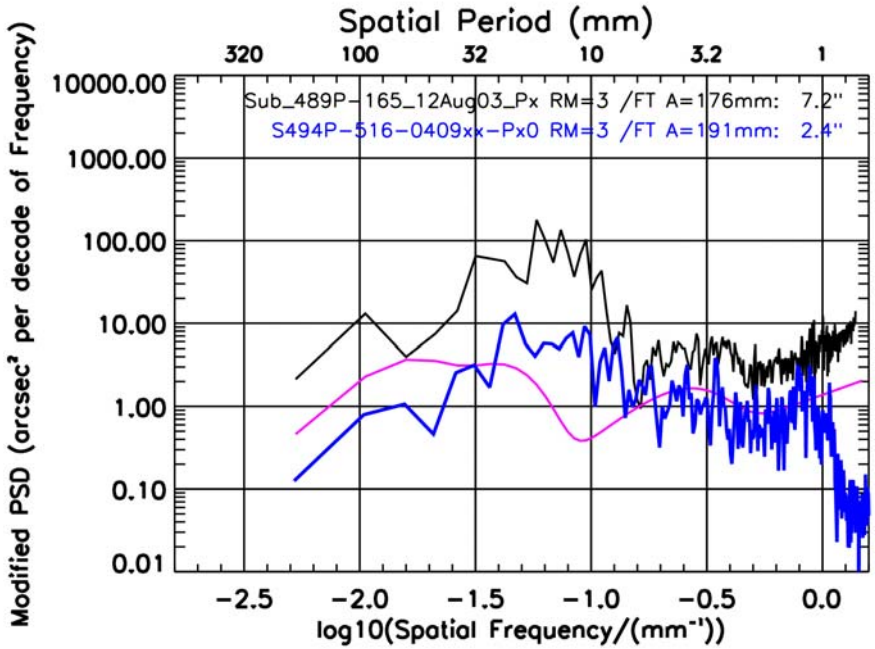




- Low Frequency Regime (spatial period: 30 to 200mm): exceeding requirement
- Mid Frequency Regime (spatial period: 5 to 30mm): not meeting requirement, currently dominating the total error; epoxy replication is expected to reduce these errors to well below the requirement
- High Frequency Regime (spatial period: 1 to 5mm): meeting requirement, metrology noise being a large component of the error
- Very High Frequency Regime(spatial period: 1mm and less): meeting requirement

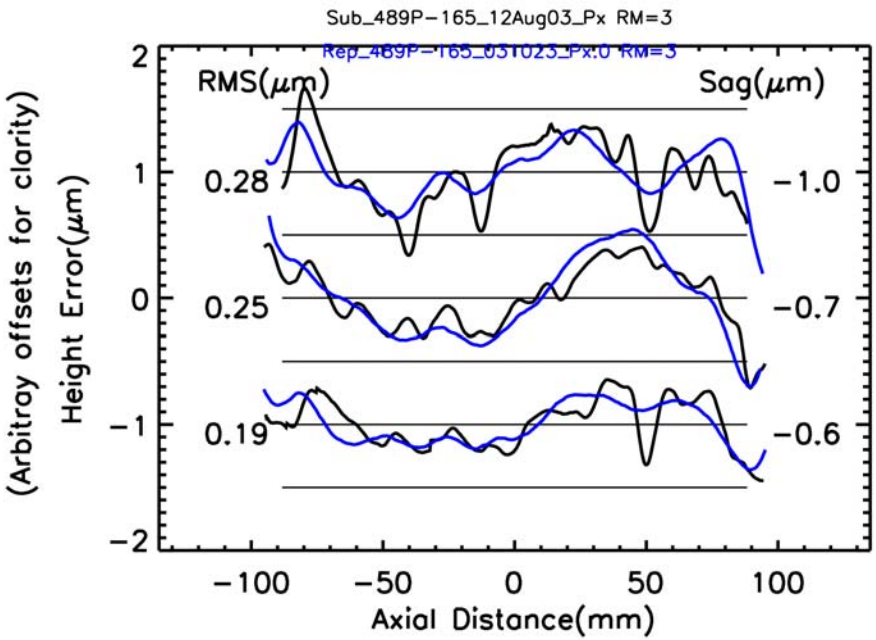
Comparison: 2003 (black) and 2004 (blue)

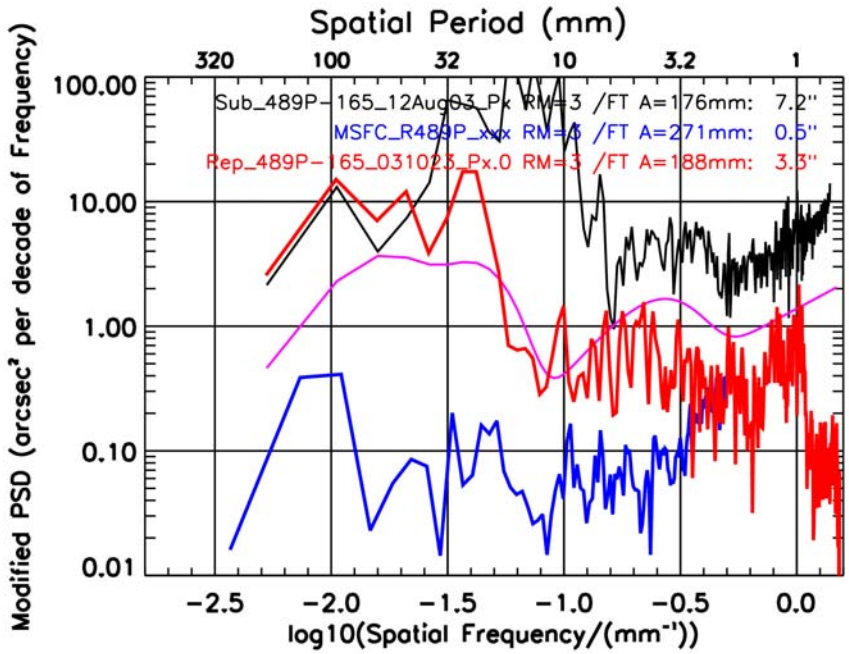




- A factor of ~3 improvement in substrate quality from 2003 to 2004
- Latest substrates without replication can almost meet SXT baseline requirement

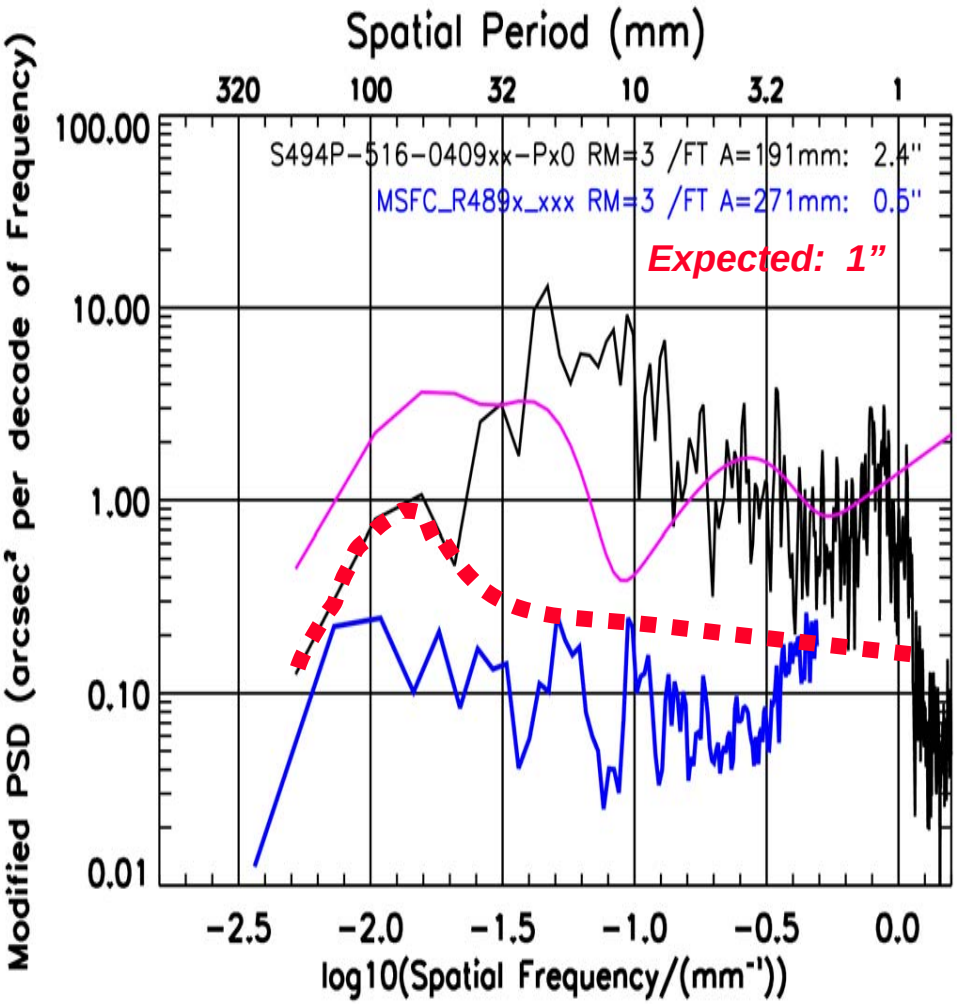
Demonstrated Effect of Epoxy Replication Using a Poor Substrate from 2003





- A replication with 5μm epoxy improves the figure by
  - A factor of ~3 in the high frequency band
  - A factor of ~5 in the mid frequency band
  - Nothing in the low frequency band

What to Expect for the Next Replication



- We have shown that 5μm or thinner layer of epoxy does not distort the replica figure
- The recent substrate has an axial figure error on the order of 60nm RMS
- Experience has shown that 5μm epoxy can totally mitigate the 60nm RMS error
- When the recent substrates are replicated correctly (after a few practical logistical problems are resolved), we expect the final replicas to have an axial slope error close to ~1″ RMS, corresponding to a ~4″ (HPD, 2 reflections) assembly performance

Technology Status, Problems, Solutions, and Prospects

- **It is all but certain that the current technology can meet, and most likely can exceed, the SXT baseline requirement:**
  - **15″ (HPD 2 reflections here and hereafter) at the observatory level**
  - **12″ at the individual telescope level**
  - **10″ at the mirror segment component level**
- **Current Problems and Solutions**
  - **Cleanliness of the substrate forming environment**
  - **Cleanliness of the replication mandrel coating environment**
  - **Cleanliness of the epoxy replication environment**
  - **Solutions: procurement of a clean oven, enclosing the replication mandrel coating process in a clean environment**
- **Prospects**
  - **In one year:**
    - **Fabricate segments meeting baseline requirement on a routine basis**
    - **Probe the pathway to meet the SXT goal of 3.5″ (HPD, 2 reflections)**
  - **In two to three years:**
    - **Procure forming/replication mandrels that meet the SXT goal**
    - **Build up infrastructure that can fabricate and measure the 3.5″ mirrors**